Appendix B

Parameters, Approach, Assumptions, and Degree of Conservatism Used: Land Application Risk Assessment

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Pollutant Limit Is:			
RP	Cumulative or annual application rate of pollutant that can be land applied without expectation of adverse effects: cumulative rate—nondegradable pollutants (inorganics; aldrin/dieldrin, chlordane) annual rate—degradable pollutants (organics)	Certain pollutants assumed not to degrade in environment	C—Many of the parameters used to calculate RP or RSC are conservative, resulting in inherently conservative pollutant limits
or			
RSC	RSC based on poll. conc. in biosolids was calculated (except for lead, Pathway 3) by relating human or animal health/exposure parameters (e.g., RIA, TPI) to exposures from biosolids/ soil: —parameter for the ingestion of poll. in biosolids/soil by children (I_s), or —uptake of poll. in plant tissue (consumed by animals) and of animal tissue consumed by humans (UA), and parameter for fraction of animals' diet that is biosolids		

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Pollutant Limit Is (continued):			
RSC (continued)	Lead pollutant limit determined using EPA's Integrated Uptake Biokinetic Model (IEUBK), for lead (Pathway 3)	Policy decision for lead to set limit lower than number derived from IEUBK to provide additional margin of safety (i.e., from livestock data on lead)	
Health Parameters:			
RIA	Health-based value (e.g., RfD or q_1^*) adjusted for body weight, with exposure to pollutant from sources other than biosolids (food, water, air) subtracted		C—Designed to protect most sensitive members of population from biosolids pollutant; based on conservative RfD or q_1^*
RfD or q_1^*	See Chapter 2, Box 3 If pollutant associated with both cancer and noncancer effects, cancer was used as most sensitive endpoint unless the cancer was associated with a different route of exposure	Continuous 70-yr lifetime Any exposure to carcinogen has a risk (q_1^*) Threshold (i.e., minimal risk) levels exist for noncarcinogens (RfDs)	C—Both RfD and q_1^* predict greater adverse effects than are likely to occur; both assume lifetime exposure, which is unlikely; q_1^* based on most sensitive species and conservative extrapolation from high to low dose; RfDs use safety factors to offset uncertainties
RL	Standard U.S. Government scientific approach used to establish cancer risk level	Lifetime (70 yr) exposure Risk level of 1×10^{-4} chosen (policy decision)	A—Risk level of 1×10^{-4} chosen because related data indicated minimal risk associated with biosolids use or disposal
BW	Standard adult male value used Two alternative values for child weights	Adult: 70-kg (154 lb) male (except Pathway 3); Child: for Pathway 3 — Child (ages 1-6) = 16 kg (35 lb) for agricultural land and (ages 4-6) = 19 kg (42 lb) for nonagricultural land	A (adult)—Average value used A (child)—Peak absorption age is 1.5 years
RE	RE value of 1.0 was based on EPA policy to be conservative; REs of less than 1.0 should be used only where good data exist on RE or pharmaco-kinetics; limited data existed for this risk assessment	Relative effectiveness of exposure (RE) = 1 (compares exposure routes, e.g., ingestion vs. inhalation)	C—A value of 1 probably overestimates risks through food consumption
RF	Poll. conc. in human or animal diet (RF) was needed to calculate soil-based RSC value; RF relates health parameter (e.g., RIA, TPI) to uptake (UA) and dietary (DA, FA) parameters	100% of livestock diet consists of forage grown on biosolids-amended land (Pathway 6)	A—It is not unusual for livestock to forage on biosolids-amended land

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Health Parameters (continued):			
RC_{sw}, RC_{air}, RC_{gw}	RC_{sw} based on the smaller value of the risk assessment calculation, chronic or acute freshwater criteria for the poll., or LOAEL; RC_{air} based on q_1^* and RL; RC_{gw} based on q_1^* and RL for organics, and MCLs for inorganics	Distance to well = 0 Buffer zone = 10 meters (bet. biosolids management area and nearest body of surface water) Soil type = sandy soil	C—Based on conservative health criteria and assumptions
RC_{gw}	Background pollutant concentration values subtracted from MCL to derive reference (allowable) water concentration	If background concentration of pollutant was below the detection limit, assigned a value to the background concentration equal to one-half of the detection limit Background conc. of organics = 0	A
RC_{lec}	Models used to simulate flow and transport of pollutants through soil and ground water: — VADOFT (from RUSTIC) model (unsaturated zone) — AT123D model (saturated zone)	The overly conservative approach in the proposed risk assessment was changed for the revised risk assessment to more realistically assess the portion of a pollutant transferred to ground water (e.g., fate and transport models [CHAIN and MINTEQ] used for pollutants in the unsaturated zone were replaced with a more appropriate model [VADOFT]); assumption that 100 percent of a pollutant could be simultaneously transferred to ground water, surface water, and air, was changed to a "mass balance" approach; more realistic, site-specific geologic, hydraulic, and chemical parameters were used as inputs to computer models).	C—Results well within acceptable EPA risk levels
TPI[c]	Based on recommendations of experts about best available data on most sensitive and most exposed species	Shrews and moles assumed to be the most exposed species for cadmium and lead (most sensitive species not identified) (Pathway 10) Chickens believed to be a more representative species (e.g., than mink) for PCBs (Pathway 10)	C—Based on most sensitive or most exposed species

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Environmental Parameters:			
RLC	Because plant uptake of organic pollutants was regressed against soil concentration, a reference (allowable) pollutant concentration in soil was calculated (RLC), which was then converted to an annual application rate (RP) (Pathways 1, 2, 4)	Limit based on available data adequately protects soil organisms from adverse effects	A—Because data available for only a few species
	Based on best available data (NOAEL for earthworms) (Hartenstein et al., 1980), although no species identified as the most sensitive/most exposed (Pathway 9)		
PT_{50} or TPC	Limit based on PT_{50} for corn, or TPC for most sensitive/exposed species, whichever resulted in the more limiting number in calculations	Short-term retardation in growth of young plant may reflect some level of reduced yield at maturity (PT_{50})	C—Most conservative result of PT_{50} or TPC chosen as poll. limit; short-term phytotoxicity often does not result in yield reduction at maturity; TPC more sensitive indicator of phytotoxicity than PT_{50}
	Calculation for TPC based on biosolids field studies	0.01 = probability (99 times out of 100) that the PT_{50} concentration was not exceeded in field studies; PT_{50} was set as the tissue concentration that was not to be exceeded	
	Based on literature search (computer databases and 2,713 original articles) (PT_{50})	Agricultural pollutant limits also protect wild species in nonagricultural settings (based on lit search) (PT_{50}, TPC)	
	Only PT_{50} approach used for chromium because data unavailable for TPC approach	Uptake of pollutants is through plant roots (PT_{50}, TPC)	
Dietary Consumption Parameters:			
DC	EPA Estimated Lifetime Average Daily Food Intake, based on surveys/studies of dietary intake (reanalyzed Pennington 1983): food consumption for different age groups among males and females were averaged and used to calculate a lifetime weighted average intake (Pathways 1,2)		A—Food consumption averaged over a lifetime
	EPA reanalysis of FDA Revised Total Diet List (1982) (Pathway 2)		

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Dietary Consumption Parameters (Continued):			
DA	Estimated Lifetime Average Daily Food Intake (see DC above); only animal tissue food groups used for DA	Human food consumption of products from animals that have ingested biosolids ranges from 3-10% depending on food type (Pathway 5) HEI consumes animal tissue foods daily (ag and nonag pathways) (Pathway 4)	A—Food consumption averaged over a lifetime
I_w, I_f	Daily consumption of fish (Javitz, 1980) and water (standard EPA assumption).	HEI consumes 2 liters/day of drinking water and ingests 0.04 kg/day of fish from surface waters into which soil eroded from a site where biosolids were applied	C—The fish value is highly conservative for the population, and the water value is high-end but not as conservative as the fish value
I_s	EPA OSWER recommended value for amount of soil ingested by a child each day for 5 years from age 1 to 6 (U.S. EPA, 1989b)	0.2 g/day = soil ingestion rate for children Biosolids not diluted with soil Child is not a PICA child	C—Designed to protect children at highest risk, except: A—Does not consider pica child (a pica child is one who has an abnormal craving to eat materials other than food, such as soil and dirt)
Parameters for Fraction of Diet Produced on Biosolids-Amended Land:			
FC	Adaptation of estimates of % of human diet crops grown on biosolids-amended soils (from CAST 1976) x % of biosolids land applied (Pierce and Bailey 1982) (Pathway 1)	2.5% = amount of human diet (vegetables, fruit, grain) (except for home gardener) grown on land receiving biosolids (agricultural) (Pathway 1) 25% = fraction of evaluated foods (berries, mushrooms) produced on biosolids amended soil (nonagricultural) (Pathway 1)	A—Amount of food grown was reduced to exclude crops not consumed by people (i.e., crops consumed by animals) (Pathway 1)
	Based on USDA survey of homegrown foods (1982)	HEI produces 37-59% of own crops grown on biosolids-amended land, varies depending on food group (agricultural; not analyzed for nonag) (Pathway 2)	C—Very few home gardeners actually grow 59% of the leafy vegetables they consume, on land amended with biosolids, continuously for 70 years (Pathway 2)
FA		Fraction of food group assumed to be derived from animals that ingest forage grown on biosolids-amended soil ranges from 3-11% depending on food type (agricultural) and 100% (deer) and 50% (elk) (nonagricultural) (Pathway 4)	A—for livestock farmers C—for U.S. population

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Parameters for Fraction of Diet Produced on Biosolids-Amended Land (Continued):			
FS	Weighted average chronic lifetime model, based on cattle biosolids ingestion studies, adjusted for % of biosolids-amended land	1.5% = fraction of biosolids ingested by grazing animals on land amended with biosolids 30 days prior to grazing (averaged over a season) (Pathways 6,7)	A—Averaged over a lifetime
	Based on 2.5% ingestion of biosolids from pastures in year of biosolids application and 1.0% in non-application year	33% = maximum fraction of a farm's area amended with biosolids in any one year (Pathways 6,7)	C
FD	Based on available studies of earthworm consumption (McDonald, 1983)	33% = fraction of earthworms in predator's diet (Pathway 10)	C—Based on maximum chronic consumption of earthworms by wildlife
Parameters for Plant Uptake of Pollutants:			
UC	$\frac{\textit{Plant tissue concentration}}{\textit{Metal application rate}} = \textit{Slope}$	Plant uptake is linear (increases as more metal added)	C—Plant uptake of metals in biosolids is, in fact, curvilinear (plateaus), i.e., metals become less available to plants over time, even if more metal added (see Chap. 3); also, data from high-metal studies were included
	or, linear regression	0.001 = default value for plant uptake slope for inorganics when slope was negative or <0.001, or when no data available, and for all organics	
	Based primarily on field studies; some field spiked-metal or greenhouse/pot studies, or other non-biosolids metals studies used when field studies unavailable	Geometric mean used (see UA below)	
UA	Animal tissue uptake slopes calculated (regression): $\frac{\textit{Concentration of poll. in animal tissue}}{\textit{Concentration of poll. in feed}}$	Geometric mean used to average plant and animal uptake slopes from different studies	C
Loss Factor Parameter:			
K	Mass balance (see Appendix A)	8.5 mt/ha · yr = annual losses to erosion (USDA, 1987)	A
		Mass balance, organics: assumes equilibrium reached (annual loading of poll. = annual loss of poll.); thus organics could be applied indefinitely in water or air because they do not accumulate	
		Mass balance, inorganics: assumes equilibrium not achieved; conc. of poll. assumed to increase with repeated applications until limit reached; based on max. predicted av. conc. of poll. in surface water over 70 yrs.	

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Background Parameters:			
TBI	Background intake rate of pollutants from sources of exposure other than biosolids was subtracted from RfDs/q_1*s; remainder = amt. of poll. from biosolids that will not exceed threshold		A—Average background values used
BS	Background concentration of pollutant in soil (BS) subtracted from allowable soil concentration to determine allowable pollutant concentrations in soil from biosolids	Median background inorganic pollutant concentrations in agricultural soils used (Holmgren et al., 1993) Background soil levels of organic pollutants = 0 (i.e., for organics the amount of pollutant applied annually is assumed to be degraded at the same rate it is applied—is in equilibrium)	A—Average values used
BC	Geometric mean of background pollutant concentration in plants grown in *non*biosolids-amended soil = BC		A—Average values used
Bioavailability and Bioaccumulation Parameters:			
BAV	Based on available studies, which indicate that pollutants are not 100% available	Bioavailability factors: Cadmium = 21.4% for a highly contaminated heat-dried biosolids (the BAV for Part 503 Table 3 biosolids = near 0%) Lead = 40% (BAV usually far under 5%; cows retain less than 1% of ingested Pb) PCBs = 100% (biosolids PCBs = 50%)	C—Assumptions overestimate pollutant availability in biosolid
BACC	Analogous to use of uptake slope in other parts of the risk assessment; BACC describes conc. of poll. present in earthworms because of bioavailable poll. conc. in soil	Bioaccumulation factors: Cadmium = 6 Lead = 0.45 PCBs = 3.69 (µg-pollutant/g-soil biota DW) (µg-pollutant/g-soil DW)$^{-1}$	A
Parameter for Exposure Through Inhalation:			
MDC, based on:		1 meter = distance from tractor driver to soil surface (Pathway 11)	
NIOSH TDA	NIOSH-recommended standards (Pathway 11) American Conf. Gov. Indus. Hygienists (ACGIH) recommendation	10 mg/m^3 = max. dust level exposure (above this level, ACGIH recommends closed cab) (Pathway 11)	C—Within acceptable government risk levels

Parameter Used in Calculation of Pollutant Limit[a,b]	Approach or Basis	Assumptions/ Policy Decisions	Parameter Is Conservative (C) or Average (A) and Why
Parameter for Exposure Through Inhalation (continued):			
RF_{air} (Pathway 13)	Only organic pollutants evaluated because inorganics do not volatilize at ambient air temperatures	Inhalation rate = 20 m^3/day of air contaminated with pollutants from biosolids Wind direction assumed never to change, keeping HEI downwind of site HEI lives at downwind boundary of biosolids management area	C—Exposure will not always occur downwind of the site and at the site boundary
Parameter for Exposure Through Ground Water:			
TP	See Appendix A	300-yr. ground-water contamination simulation model used Site receives worst-case 1,000 mt/ha application (over 60 cm on surface) (policy decision) Depth to ground water = 1 meter Soil type = loamy sand Porosity = 0.4	C—Depth to ground water may be more than 1 meter; worst-case application rate used; based on pollutant transport over 300 years

[a]Appendix A describes the parameters used; Chapter 3 discusses issues involving some of the key parameters.

[b]Boxes 9 to 14 (in Chapter 4) provide examples of how the parameters were used to calculate pollutant limits for biosolids.

[c]Threshold pollutant intake level (TPI), *or* tolerable conc. of poll. in whole kidney, DW used (Pathway 10); also, cadmium = 4 different approaches, most limiting # used (Pathway 10).